Designing Learning for Augmented and Virtual Reality

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1 Introduction

Instructional design methodologies have been somewhat static for years. Dick and Carey's Instructional Systems Design model [1] (1978), the ADDIE model [2] (1975), and more recently the Successive Approximation Model [3], continue to be used. These models work quite well with instructor-led workshops and e-learning programs but lack extensibility in an ever-changing technology environment. The introduction of new technology platforms such as virtual reality (VR), augmented reality (AR), and mixed reality (MR) require the instructional designer to take a new approach to ensure learners walk away with skills and knowledge they can transfer to their workplaces.

This white paper will explore what instructional designers should consider to ensure that VR/AR/MR platforms deliver the maximum learning benefit. Leveraging known learning theories to ensure learning occurs, while applying new methodologies relevant to the selected technology platforms, will deliver the highest levels of learning for today's skilled workforce.

Keywords:
Learning
Augmented reality
Virtual reality
HoloLens
ADDIE
3DLE

2 A Little History of Learning

Since the 1970s, learning programs have been designed and developed using the Instructional Systems Design (ISD) model by Dick and Carey. Their model brought structure to the design of learning, ushering in seriously needed transformation. The result was substantial improvement in the effectiveness of training solutions.

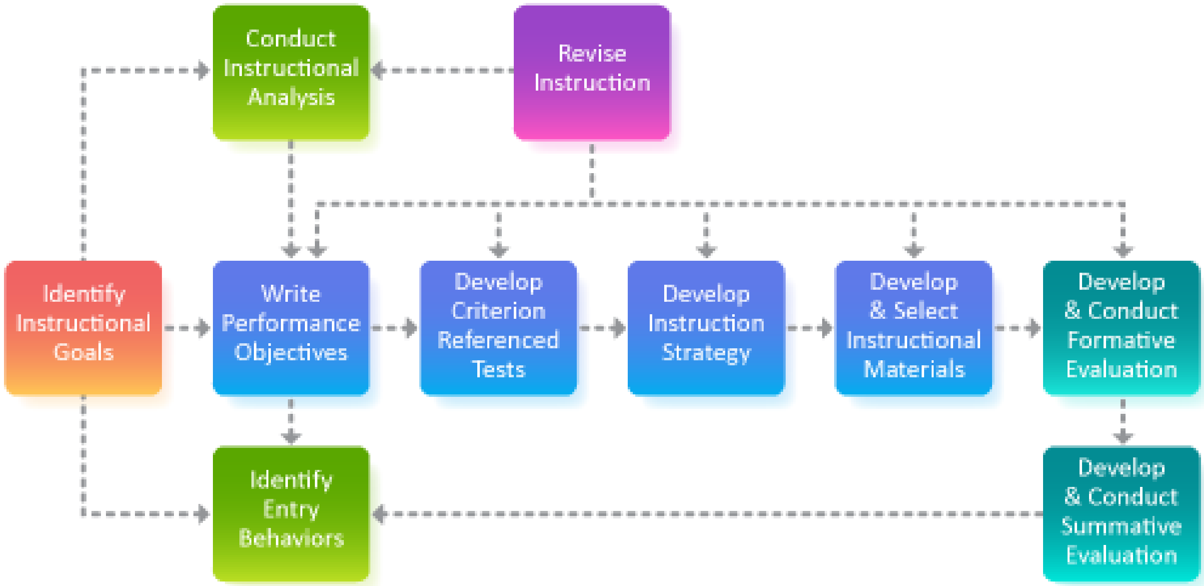

Figure 1. The Dick and Carey Model

Another learning program development model known as ADDIE (also known as the Waterfall model) consists of five phases: Analysis, Design, Development, Implementation and Evaluation. In the ADDIE model, each phase has an outcome that feeds into the subsequent phase. The ADDIE model has been widely adopted throughout the world by instructional designers and training developers.

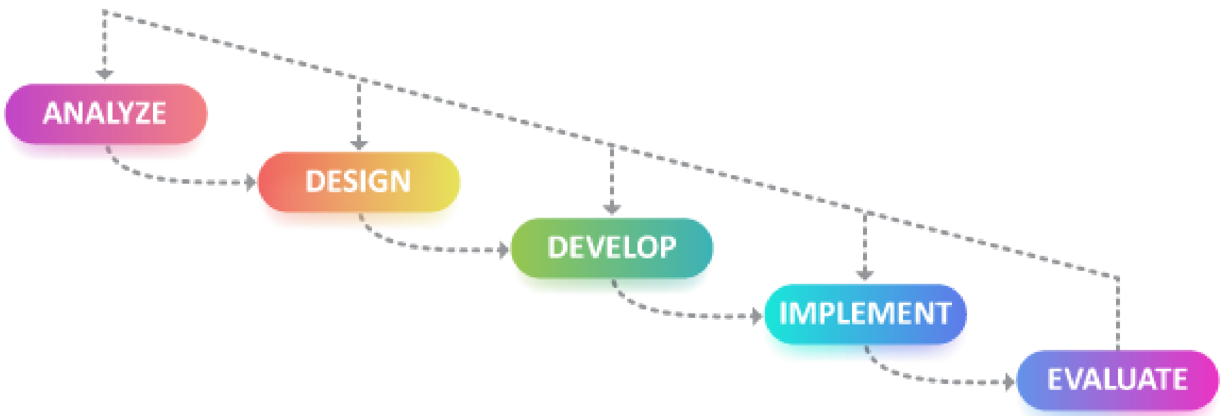

Figure 2. The ADDIE Model

Use of these models has been widespread since the early 1970's and they are still used today for designing and developing many face-to-face and virtually-led learning programs. Additionally, many instructional designers follow them for e-learning [4] programs.

However, e-learning program design methodology has evolved since the 1990's and many new processes have been introduced to help in design and development. Examples include Rapid Instructional Design, rapid prototyping of e-learning programs, and two Agile-based models – Successive Approximation Model (SAM), and Dick and Carey Systems Approach Model.

3 What's Happening Today

Today's world of electronic learning includes synchronous and asynchronous [5] environments. Synchronous virtual environments include real time interaction with two-way communication via teleconferencing software. Some of the more popular platforms are Adobe Connect, WebEx, Zoom, and GoToTraining. Asynchronous e-learning is done at the student's own pace at any time via computer and web browser.

Increasingly, training in the current ear uses new technologies and media accessed on smart phones and tablets. These include training with social media [6] (e.g., blogs and Facebook groups for student classes); social learning [7] (interactive real time collaboration); and micro learning (a performance support tool that requires less than five minutes of the user's time).

The learning and skill development world is changing rapidly. These historical learning program design methodologies remain relevant, but need to evolve as a new generation of technology and tools – virtual reality (VR), augmented reality (AR), and mixed reality (MR) – become available and affordable.

4 What's Next?

VR, AR, and MR (defined below) are transformational performance enhancement technologies that are being adopted rapidly in several industries and for a wide variety of use cases. The technologies are not new. For over twenty years, organizations have been employing VR, AR, and MR to enhance workforce skill and knowledge levels. VR, AR, and MR systems have not been in the mainstream due to their high cost and complexity. In recent years however, the cost of the technology has gone down significantly and the quality of the hardware has improved markedly, making adoption of these systems more prevalent.

4.1 VR

Virtual reality replaces our environment with a completely different environment – an artificial world in which you are immersed. This includes visual, audio, and in some cases full haptic experiences. VR delivers a 360-degree environment via head-mounted display or goggles, and in some cases a haptic suit [8] which enables you to touch and be touched in the simulated environment.

Companies like Boeing and McDonnell Douglas have built their pilot expertise on the backbone of the VR flight simulator. The flight simulator is a complete immersive experience in a chamber that looks, feels, and sounds like the cockpit of an airplane. Pilots who fly for major airlines have gone through 50 to 100 hours of simulator training, plus additional hours each year. This ensures their knowledge of a specific airplane and that its instrumentation is mastered. Astronauts have spent hundreds of hours in simulators, mastering the different space vehicles so they can perform tasks when in orbit around Earth. To simulate weightlessness during training, astronauts are not just immersed in their new environment, but also submersed (to simulate weightlessness) in a large tank of water where they practice their tasks.

The gaming industry utilizes VR simulation software to immerse their players in realistic fictitious environments. They incorporate 3D interactive visual effects along with avatars and real-time coordination of players to make the game experience as real as possible. All of these gaming technologies are now available for incorporation in virtual reality learning simulations for a variety of uses.

Forward-thinking service companies are assisting organizations in making these technologies viable across a broad range of industries. For example, Train Point, LLC [9] is a safety training company that specializes in virtual reality training exercises. Train Point uses VR to immerse the user in a training environment, to create realistic situations, and to control the environment and events externally while the user works through procedures. Exercises such as Lock Out Tag Out, Entering Confined Spaces and Hazard Identification have both a single player mode and a multi-player mode. This is just the tip of the iceberg for the use of VR in training. Train Point is currently working on artificial intelligence (AI) avatars and ways to engage the user and collect data to reinforce behavior change. [Source: Epsilon Systems]

Figure 3. Train Point Safety Training
Image Source: Epsilon Systems

4.2 AR

Augmented reality technology expands our view of the physical world. It adds layers of digital information onto what we can see naturally. It augments our surroundings by adding data, images, sound and video. It is often referred to as spatial computing. AR content is made visible via several types of human interfaces, including glasses, projectors, smart phones, tablets, large screens, and head-mounted displays.

For example, the Augmedics [10] AR head-mounted display for spine surgery is called *xvision*, because it gives surgeons a kind of x-ray vision during a procedure. According to Augmedics, the device determines the position of surgical tools in real-time and superimposes them on a patient's CT data. That display is projected onto the surgeon's retina using a headset, allowing him or her to simultaneously look at their patient and see the navigation data without looking to a heads-up display elsewhere. The outcome is quicker, safer, and more precise and thorough procedures resulting in better patient outcomes. [Source: Nanalyze.com]

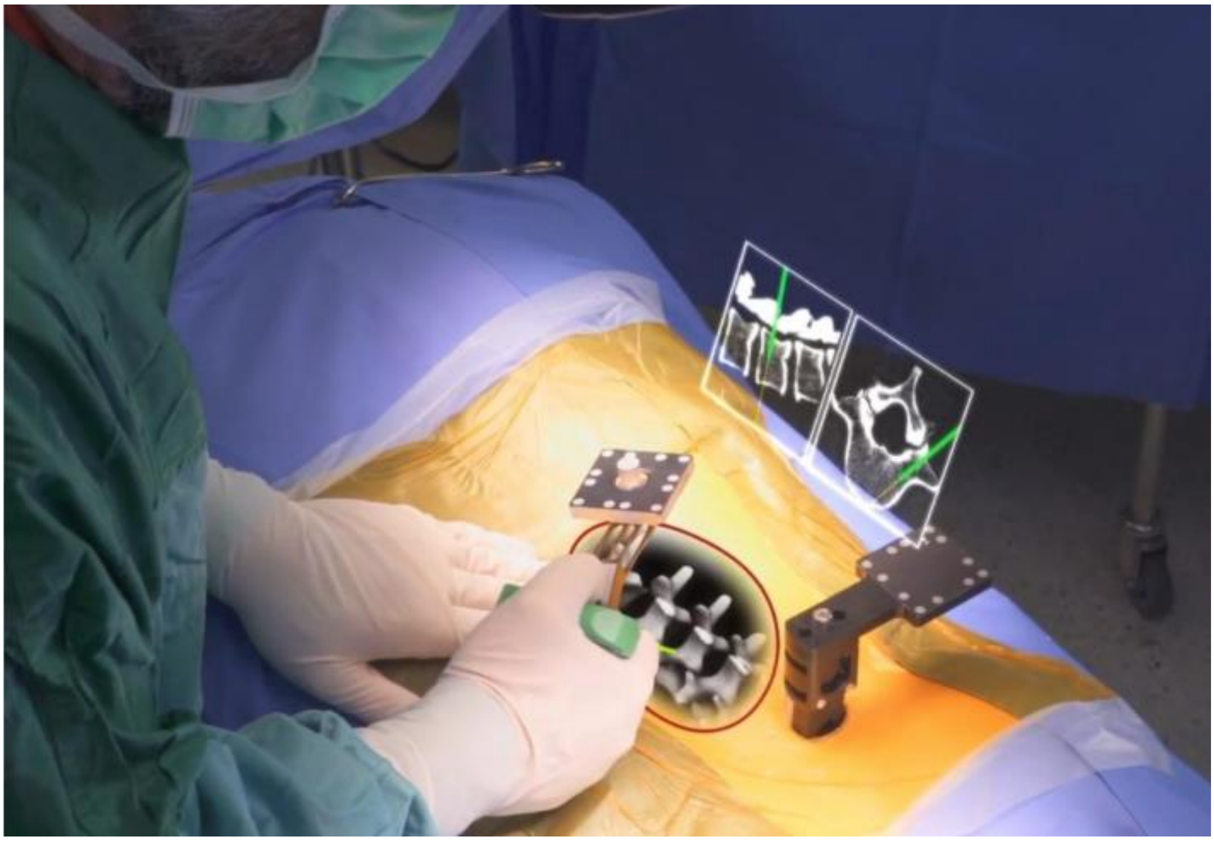

Figure 4. Augmedics' AR platform
Image Source: Augmedics

Whether teaching anatomy to medical students or displaying a patient's x-ray images to a surgeon as an overlay, AR brings a deeper real-time view beyond our normal vision.

4.3 MR

Mixed reality is, as its name suggests, a mixture of AR and VR. An MR environment combines the AR view of your environment with virtual objects that also reside in this environment. For example, you may be looking at an actual operating table in an operating room with a virtual patient lying on it. As you move around the operating table, you can view the virtual patient from any angle.

According to Case Western Reserve University [11], visualization has long helped us understand the abstract by morphing various analyses into pictures. Viewing items in three dimensions helps us understand how they really appear; augmented, virtual, and mixed reality (AR/VR/MR) technology allows us to be in a visual space to help us understand various scenarios.

Technology is finally evolving that has the potential to revolutionize teaching and learning, research, entertainment, and information sharing for the individual. For example, the Microsoft HoloLens offers the ability to teach and learn in a mixed holographic reality. Users can see how the aortic valve in a heart actually works, collaborate with experts near and far, and see what others see – all in real time. Students can learn about geography not only by reading or watching a video but also through being immersed in it. Their brain believes they are there. They have an emotional response to this experience and they learn more holistically. [Source: Educause Review]

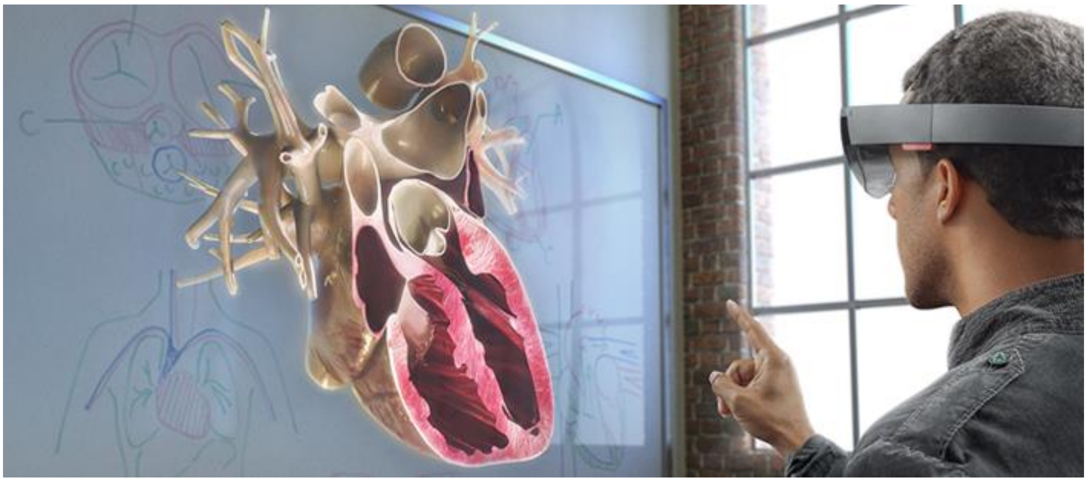

Figure 5. Case Western Reserve University and Cleveland Clinic's HoloAnatomy Image source: Microsoft

5 Lessons from E-learning

From our experience over the last 30 years producing learning programs for both asynchronous and synchronous environments, we have learned some fundamental lessons. We've learned not to create an electronic book for learners to page through and expect them to simply read and learn. We've also learned not to expect learners to sit and listen in a webinar while an instructor lectures for hours.

For learning to occur, whether in a digital space or in face-to-face settings, we need to engage the learner and help them make the information their own. The learner needs to embrace the responsibilities of being in the learning space and take ownership of how they will transfer skills and knowledge to their workplace.

As a result, our experience has provided the VR/AR/MR instructional design world with a head start. Our knowledge of learning engagement, cognitive overload, learner responsibility, and learner-centered modules benefits us and provides a foundation as we move into these new media formats for learning. We can leverage this knowledge and skill as we start to develop the best learning experience possible for our learners while applying the latest and most powerful learning technologies.

Five key lessons from e-learning that should help guide VR/AR/MR courseware development goals:

1. Make a relevant learning experience. When creating VR training, make it relevant to the task you're training. Stay focused on the objective and complement the scenario with real-life elements that the user will see on the job.
2. Create student participation and engagement opportunities. In VR there are plenty of opportunities for this: creating events that happen in the environment, where an avatar interacts with students by directing them or asking questions.
3. Stimulate using engaging visuals and interactive media. A lot of effort should be devoted to the graphical side of VR. If you're going to immerse the student in a 3D work environment, make it look as real as the budget allows. Don't use elements that take away from the reality of the environment. Avoid floating menus or anything that detracts from the realism of the scenario.
4. Schedule just-in-time events and information to improve student participation. Allowing the students to have access to smaller, more specific blocks of information at the point of need has proven to be more productive.
5. Create knowledge-based reachback/feedback. Course content must support your objectives, and that is still true in AR/VR. And the knowledge base can go much further. Sometimes supporting information is needed to help reinforce the content or to give feedback. Artificial intelligence can deliver additional content and provide more responsive and dynamic feedback than a programmed feedback loop.

6 Learning Methodologies

AR and VR learning experiences are different from one another and so are the learning methodologies associated with designing and developing them. Instructional design (ID) for AR is based on the traditional ADDIE or SAM model, but with some key enhancements specific to AR technology. ID for VR leverages additional layers in the analysis and design phases. These enhanced models are discussed in more detail below.

7 AR Learning Methodologies

Designing learning for AR applications is very similar to designing for e-learning applications – the ADDIE model fits quite well for both. Some general guidelines that apply to both e-learning and AR learning are expressed in Wasko's dissertation on *Instructional Design Guidelines for AR* [12]. These guidelines enhance the design phase of the ADDIE model.

- Use both words and pictures and use them appropriately. Employ the multimedia principle that people learn better from words plus pictures than they do from just words. AR, after all, is a visual experience. In some cases, adding words via text or audio is enough of an augmentation. But adding visual overlays, or spoken words plus visual overlays, results in a deeper learning experience than text-only overlays.
- Use spoken text instead of printed text. The AR learner is already using the visual learning channel to see the real-world environment. Overlaying written text requires the learner to split this channel and process two visuals simultaneously. Using spoken text allows the learner to use two separate channels for enhanced learning.

- Make sure related words and pictures are presented at the same time. Working memory is limited in capacity. Showing instructions followed by showing an animation requires the learner to remember the instructions while viewing the animation. Overlaying spoken instructions simultaneously with showing an animation results in deeper learning.
- Do not add unnecessary information to your instruction. Unnecessary audio (such as background music), stories/ anecdotes, or visuals distract the learner. Provide the learner with only essential material and this will make it easier for the learner to comprehend.
- Use a conversational tone. Research has shown that learners experience deeper learning in a multimedia environment when the instruction is in a personal conversation style rather than a formal style. Establishing a sense of social partnership with learners makes the content more meaningful to them.

Epsilon Systems leverages AR software and content development platforms to design AR learning applications. These platforms can be used for experience delivery via a variety of user interfaces such as glasses, head-mounted displays, projections, tablets, smart phones, and large screens.

8 VR Learning Methodologies

While new technologies for VR learning are transformational, the effective design and development of VR learning leverages design traditions from the past 50 years. But VR learning uses a more layered approach to creation than in the past. ADDIE, SAM, rapid prototyping, and game design are built upon to create this layered approach to VR design.

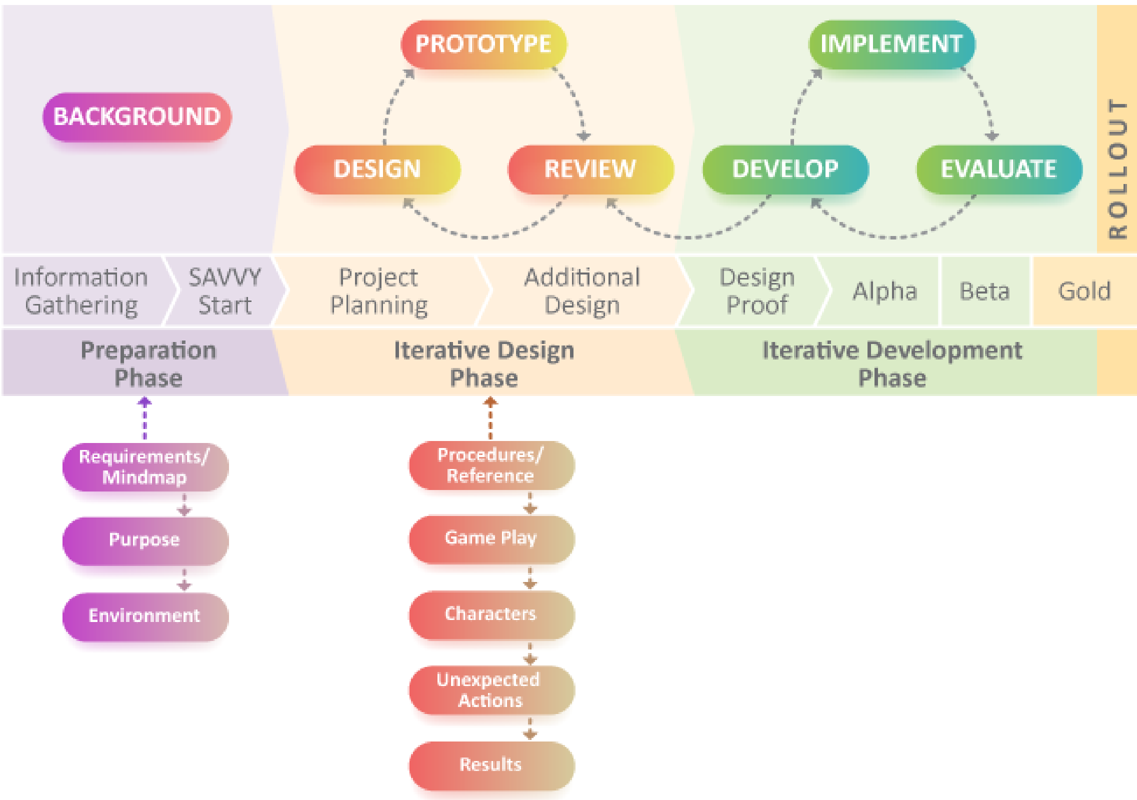

Figure 6. SAM model with Enhanced Storyboard Overlay for VR Learning

The current Epsilon Systems model for VR training solutions is shown in Figure 6 above. It consists of eight layers of enhanced storyboard that are mapped across the SAM model.

- Preparation Phase
    1. Requirements/Mindmap
    2. Purpose
    3. Environment
- Interactive Design Phase
    4. Procedures/Reference
    5. Game Play
    6. Characters
    7. Unexpected Actions
    8. Results

The enhanced storyboard is broken down into the detailed components shown below. The storyboard is fluid and changes throughout the iterative phases.

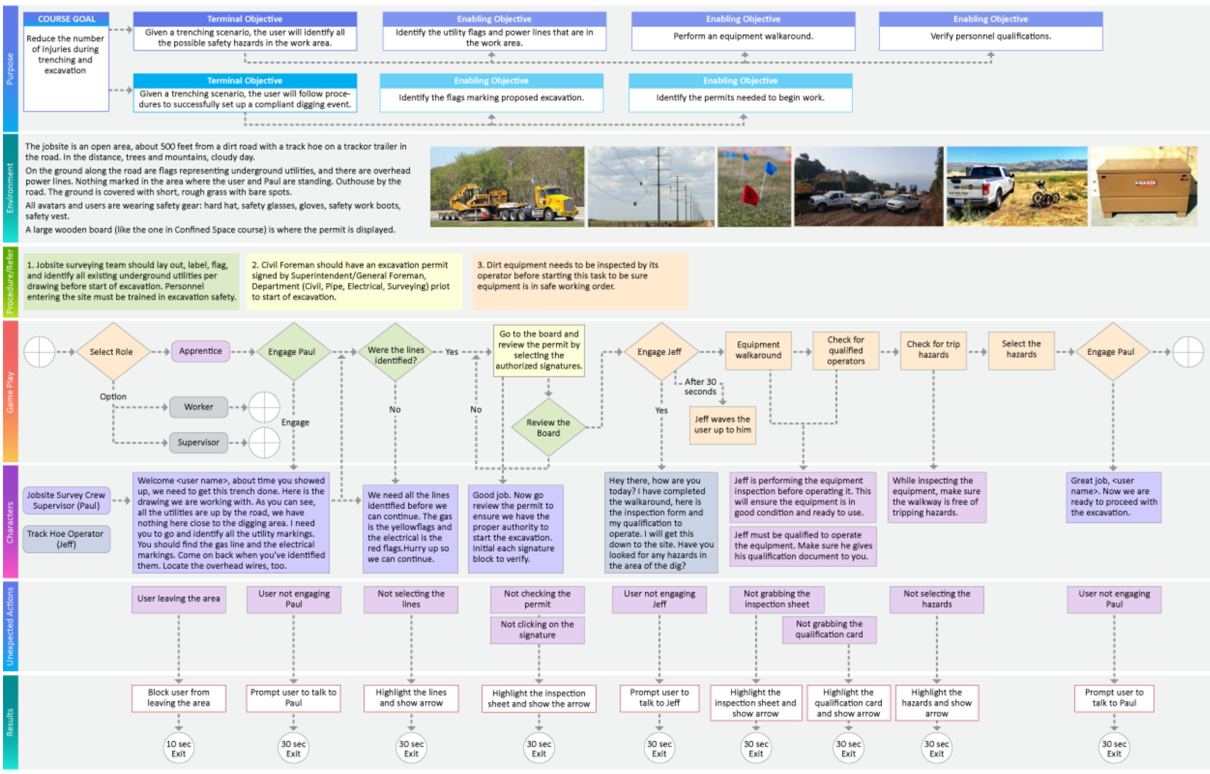

Figure 7. Enhanced Storyboard
[Link here to online version: TBD]

8.1 Preparation Phase

8.1.1 Requirements/Mindmap

The requirements are the foundation of the training experience. As with any other training content creation process, this is where the scope and overall purpose of the project are determined. The VR training should not replace current training curriculum, but supplement it and make the overall training and outcome better.

The creation process for VR learning starts with requirements gathering, determination of the organizational goals, how functional workflows affect the person doing the job, and who is the target worker for whom we are providing the learning program. The information and flow is organized into a mindmap to communicate to the client and ensure that elements of the scenarios are captured prior to creating an enhanced storyboard. Be sure to choose specific goals to help dictate actions, objects, and environments later on in the design process.

8.1.2 Purpose

Start by asking, what is the training goal? Is it how to use an impact drill? Is it how to remove an access cover? Is it to know that an access cover needs to be removed? This is one of the most important determinations of the entire design process. It will dictate the direction and eliminate some options for later in the design.

Next, break down the purpose into the learning goal, terminal objectives and enabling objectives. The learning goal is the overarching goal for the VR course. The terminal objectives ensure the learner has completed the tasks. The enabling objectives are a subset of the terminal objectives.

8.1.3 Environment

Create a visually appealing environment that reinforces the training and does not distract the user from the tasks at hand (unless the training calls for it, of course). The Environment includes the necessary visual elements and tools needed by the learner to immerse him/herself in the scenario. In the storyboard, it is specifically used to define ideas (e.g., images and video clips) for the 3D developers so that they can determine what they need to acquire for modeling the scenario. Epsilon Systems' modelers use 3D Studio Max and various other software to recreate realistic environments. This is a major part of the development effort; modeling the objects in detail is a key part of a realistic simulation.

8.2 Interactive Design Phase

8.2.1 Procedures

The procedure objectives and environment content are provided to the developer so they can begin to develop/program the steps to be demonstrated or accomplished in the scenario. A task analysis is performed to determine how the task will be demonstrated to the learner. Be creative with the interactions, but do not get lost in the details. Ensure the interactions add to the training.

8.2.2 Gameplay

Parts of gaming design models are layered onto the storyboard to ensure the simulation environment is as real as possible. Each component of the gameplay flow maps to an associated procedure. The flow illustrates how the learner is expected to progress through the scenario. However, the training is not always linear and allows the learner to experiment in the environment with the many ways to complete the training. When designing gameplay, make sure all paths to completion and failure are mapped.

Remember that just because we can do something really cool in VR does not mean that we should. Each menu, interaction, model, aesthetics – everything – needs to be purposeful. Be sure to keep the training purpose as the focus of this phase or you can lose the value VR brings to your training.

8.2.3 Characters

Avatars' dialogue is included to create the life-like tour guides that walk learners through the scenario. The gameplay and the associated characters create a flow that will lead the learner to the expected action. The number of characters (other workers who distract or other workers who comprise a realistic environment) can vary based on what learner level is targeted. For example if you are targeting the worker, only one avatar (the Supervisor) might be in play. This avatar is there to help guide the less skilled worker through the procedure. If however, you are targeting the supervisor, there may be several worker avatars at play. The supervisor could be expected to walk through the procedure without being shown how because of the higher level of skill possessed.

8.2.4 Unexpected Actions

The final two rows of the enhanced storyboard are provided to handle things that shouldn't happen. Business incident reports often help determine unexpected actions (e.g., on the job injury). The unexpected actions are factored into the gameplay to help the learner avoid an undesirable outcome in reality. Supported through the adoption of xAPI [13], this allows the trainer to not only know that the learner failed, but where, why, and the steps the learner took to get to the undesirable outcome. This helps pinpoint gaps in previous training, and in some cases the procedures themselves. Try to capture all of the possible unexpected actions, but do not be surprised when new ones arise after the application has been used a while.

8.2.5 Results

When an unexpected action occurs, the learner is presented with a result that is informative regarding the error or circumstance that occurred during the gameplay flow. For example, if a thunderstorm arises, the worker may have to stop and take shelter. Be sure to track important steps and actions so that you can present meaningful results.

8.3 Development

A gaming software development platform like Unity or Unreal is used to develop the VR learning. The Agile/Scrum project management methodology is used to develop the VR learning in increments or sprints. A portion of the requirements backlog is selected to be included at the start of each sprint. Upon the completion of each sprint, incremental deliverables are integrated with the core software, tested, and demonstrated to the client to get feedback and ensure the VR learning is aligned with client expectations and the learning objectives. The client feedback enters into the backlog to keep the project up to date.

8.4 Implementation

When testing and customer acceptance is complete, kits are created for final distribution. Simulations can be provided on a hardware and software kit or can be presented to the client over the internet.

Implementation also includes training the trainers to ensure proper setup and use of equipment and software. Also important is how the VR component will fit into the flow of the organization's blended training curriculum.

8.5 Evaluation

Evaluation involves measuring participant performance compared to the defined objective. The VR training, through xAPI, facilitates tracking user actions in great detail. For example, the number of steps taken within a completed task are measured and compared to the expected number; Bob interacted with the water shut-off valve for half of a second and then Bob navigated to the workbench at 12:37:42. These details can be critical in determining where the learner should focus to improve.

At the end of the learning module, the learner can view a dashboard with a scorecard that indicates how well they performed to the defined objective. If the learner didn't do something as expected, this is reported along with feedback on how to improve in the next session. In addition, the learning management system (LMS) can track the last time the VR module was completed, how well the learner did, and determine areas for improvement the next time the learner walks through the VR module. This can lead to improvements in the training. For example, observing a trend of failures of specific steps could indicate a flaw in the training or the procedure itself. Or if everyone is passing with 100% accuracy, that could indicate the training does not challenge the users. There is always room for improvement.

9 The 3DLE VR Learning Design Model

Models like ADDIE and SAM lay a foundation for creating traditional learning programs. For the new technologies to be supported with learning fundamentals, it is necessary for instructional designers to leverage new design models like the 3DLE (three-dimensional learning experience) Macrostructure discussed by Karl Kapp and Tony O'Driscoll in their book *Learning in 3D.*· [14]

Traditional instructional design models were developed when media were primarily linear and two-dimensional. Today, new ID models are needed to understand the opportunities of immersive interactive media. Interactive media are dynamic (change in time) as a result of learner's actions and therefore, make learning self-organized. This self-organization has a dynamic relationship with the analytics that drive the ecology of immersive environments. The former is not pre-determined, and the latter is. And that takes us to the ecology of the three-dimensional (or perhaps four-dimensional) space in which perception, attention, intention, and motivation of the learner plays as important a role as the pre-selected objectives. These affordances differentiate the traditional models and new models such as Kapp and O'Driscoll.

In a VR immersed environment these traditional design models lack the necessary foundation for allowing participants to become one with the simulated environment that they are a part of. Kapp and O'Driscoll's model builds new design principles into the VR learning that allows participants to "act and interact toward a common goal, fail, try again in a different way, and eventually (but much more rapidly and safely than in real life) achieve the desired learning objectives." [15]

The 3DLE Macrostructure is based on eight design principles and four macrostructures as shown in Figure 8 below.

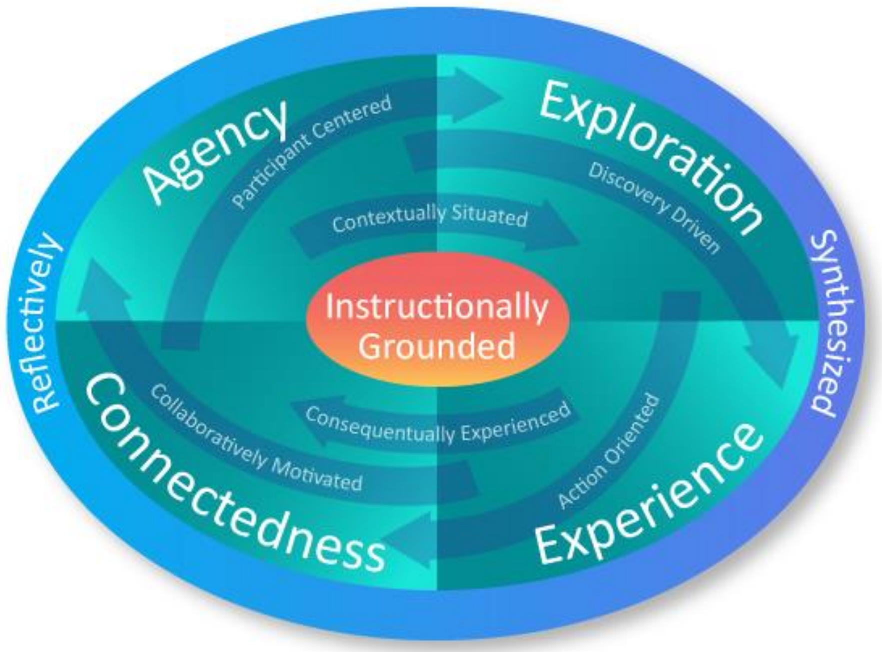

Figure 8. Kapp and O'Driscoll VR Learning Model

Kapp and O'Driscoll postulate, along with many other established instructional designers, that "any 3D learning experience should be grounded in solid instructional design. In addition, 3DLEs require reflective synthesis at the individual and team level." [16] The first two design principles are the foundation for the subsequent six design principles upon which the macrostructure is built:

- Instructionally Grounded: The learning meets a vetted business need that the learning objectives address.
- Reflectively Synthesized: The idea that all learners must reflect on what they've done before they leave the learning experience.
- Participant Centered: The participant is the one who is driving the learning experience, not the facilitator.
- Contextually Situated: The context of the learning environment is created in a 3D simulated environment where the learner believes they are able to complete the tasks in what seems like a real-life environment.
- Discovery Driven: The learner self-motivates through the flow of actions and interactions that take place.
- Action Oriented: The learner is involved in activities throughout the simulation and this is what causes the learning to happen. The learning objective is met through the action, but in a way that is not easily detected by the learner.
- Consequentially Experienced: Trial and error is embedded into the learning experience.
- Collaboratively Motivated: Rather than gathering information individually, the learner experiences collaborative and peer-to-peer learning.

The 3DLE Macrostructure Model [17] uses these eight principles and four macrostructures to create a learning architecture that is both immersive and engaging. Instructional designers are given the four macrostructures to work with, but emphasis is typically placed on just one or two of the macrostructures. The four macrostructures in the architecture are:

- Agency: The person operating the avatar is able to take action and interact with participants.
- Exploration: Navigating and examining the environment to gain knowledge.
- Experience: Engaging in activities with meaningful interactions while encountering the consequences that unfold.
- Connectedness: Interacting with each other for the purpose of creating an understanding and knowledge of the environment.

The 3DLE Macrostructure Model is a formal example of enhanced design methodology for VR. To learn more about this methodology, refer to the book by Kapp and O'Driscoll. [11]

10 Summary

VR/AR/MR are dramatically changing the way we learn by allowing us to *experience* learning rather than simply be exposed to learning material and lecture. This technology allows the ISD professional to place a trainee in any environment, any scenario, at any time, to train, reinforce, and practice safely and effectively. Prior to the current generation of VR tools, this could only take place in million-dollar simulators. VR/AR/MR are now affordable and no longer need to be reserved only for those uses which save lives, avert disaster or avoid high cost errors.

Past instructional design models like ADDIE and Dick and Carey's ISD, and SAM models are leveraged and enhanced to yield a new model enabling ISD for the VR/AR/MR immersive environment. The enhanced storyboard and the 3DLE Macrostructure Model are two examples of new approaches for designing effective learning experiences for these technologies.

In the future, artificial intelligence will provide additional data to challenge the learner's abilities based on previous learner training experience. Research indicates that these technologies will be available via hosted streaming services versus the purchase of infrastructure for training delivery. 5G wireless services bring the low latency, high speed wireless data transmission necessary to simulate a life-like interactive environment without a wired connection.

These technological advances and the accompanying evolution of instructional design mean that the delivery of training will no longer be in one direction – from instructor to learner. The immersive media with closed-loop feedback ensures the learner is accountable for his or her own learning experience and thus makes transfer of knowledge and skills back to the workplace quicker and easier than ever before.

10.1 About Epsilon Systems

Founded in 1998 and headquartered in San Diego, California, Epsilon Systems Solutions, Inc. (Epsilon Systems), a minority-owned business, has established an international presence with over 900 employees in 26 locations including three overseas locations. Epsilon Systems customers include the Department of Defense, Department of Treasury, Department of Energy, Department of Homeland Security, and non-profit and commercial customers.

Epsilon Systems Digital Media Team of professionals creates end-to-end blended and custom learning solutions for corporations, associations and government agencies. We combine state-of-the-art technical expertise with creative solutions to deliver results-driven training. We are a cohesive, experienced team of project managers, instructional designers, technical writers, graphic designers, web developers, database developers, and QA professionals. Our production process allows for expedited development, no matter what the solution. And we are experts in complying with industry e-learning specifications, including SCORM and Section 508 of the Americans with Disabilities Act and other federal accessibility requirements.

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Barbara Greenstein, Senior Instructional Designer at Epsilon Systems Solutions, Inc. is a Performance Improvement Specialist providing proven and creative ways to improve human performance in the workplace.

Highly regarded for her instructional design and facilitation skills, with over 30 years in the learning and development field, she helps clients put the systems in place to more effectively manage in today's changing business environment while ensuring optimal performance and job satisfaction for all employees.

She received her M.A. in Human Resource Development from Marymount University, Arlington, VA. Barbara is a Certified Performance Technologist (CPT), from ISPI. Barbara can be contacted at bgreenstein@epsilonsystems.com

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